

Article

Techno-Functional Properties of Mexican Cheese Whey Requesón Powder: Effects of Air-Convective Drying and Natural Gum Addition

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Abstract

Requesón, a Mexican whey cheese, has a short shelf life due to its high moisture content, near-neutral pH, and the limited preservation infrastructure of the artisanal cheese sector. Therefore, the development of requesón powder provides an innovative pathway to enhance market potential and expand its applications. This study aimed to evaluate the techno-functional properties of requesón powder produced through air-convective drying and to assess the protective effects of two natural gums, mesquite gum and guar gum, at concentrations of 0.25 and 0.5 g/L. Thermal dehydration significantly affected ($p < 0.05$) water holding capacity, swelling capacity, and hardness of the reconstituted powder. Although gum addition did not significantly enhance water holding capacity, it moderately improved texture and led to notable increases in swelling capacity (21–34%) and emulsifying capacity (11–20%) at high concentrations ($p < 0.05$). Structural analyses using X-ray diffraction and electron microscopy revealed that thermal dehydration induced protein aggregation and reduced microporosity, impairing rehydration performance compared to requesón powder obtained by lyophilization. These findings suggest that requesón powder production is a promising strategy for valorizing whey and extending the applications of this traditional cheese as a functional food ingredient.

Keywords: whey cheese; requesón; thermal dehydration; biopolymers; cheese powder



Academic Editor: Hilton Deeth

Received: 29 May 2025

Revised: 25 June 2025

Accepted: 27 June 2025

Published: 29 June 2025

Citation: Mazorra-Manzano, M.A.; Martínez-García, A.; Torres-Llanez, M.J.; Ramírez-Suárez, J.C.; López-Franco, Y.L.; Brown-Bojórquez, F.; Teutle-Paredes, J.G.; Lugo-Sánchez, M.E. Techno-Functional Properties of Mexican Cheese Whey Requesón Powder: Effects of Air-Convective Drying and Natural Gum Addition. *Dairy* **2025**, *6*, 32. <https://doi.org/10.3390/dairy6040032>

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1. Introduction

Global cheese production reached 22.3 million t in 2024, reflecting an average annual growth rate of 2% over the past decade [1]. Cheese production generates a byproduct known as whey, which represents 8–9 times the volume of cheese produced and contains more than 50% of the solids found in the milk used for cheese production, mainly lactose (4–5%), fat (<0.5%) and protein (0.6–1%). Whey protein is one of the most valuable components of whey, and most large-scale dairy industries process it into dry forms such as whey

powder, whey protein concentrate (WPC), and whey protein isolate (WPI). These products are highly valued in the food industry for their functional and nutritional properties [2]. Nevertheless, in small industries and artisanal factories, most of the volume is discarded into the environment or used for animal feed. Several options to transform the whey or recover its valuable ingredients have been proposed, such as whey beverage production, fermentation metabolites (e.g., alcohol, organic acids, oligosaccharides), fertilizers, unicellular protein, and others [3,4]. However, the lack of technological advancements in a huge number of small cheesemaking factories has limited their use. The production of whey cheese, known in Mexico as requesón, is regarded as the most effective method for utilizing whey among artisanal cheesemakers, as it requires minimal technological equipment, typically only stainless steel containers or tubs and a basic heat source. Artisanal requesón production mostly depends on the traditional practice of the cheese producer or regional demand. Requesón has no specific form, it is packed in recipients or polyethylene bags and maintained under refrigeration. It has a soft, spreadable, creamy, granular texture, mild flavor, and white color [5].

Requesón is a dairy product with high nutritional value, characterized by a high protein content (9–12%) and low fat content (4–8%) [5]. Dietitians recommend its consumption for physically active individuals, such as fitness enthusiasts and athletes, to support muscle growth and hasten recovery. It is also recommended for older adults to help improve muscular strength and reduce the effects of sarcopenia [6].

Requesón made by artisanal cheesemaking has a near-neutral pH (6.6–6.8) and a high protein and water content, which limits its shelf life. However, domestic refrigeration (<10 °C) is commonly used to preserve its quality for up to 7 days. In addition to refrigeration, packaging, aging, and drying techniques can extend its shelf life for direct consumption or as a functional ingredient in food formulation (Felix Da Silva et al., 2017 [7]). Requesón powder production could represent an attractive option for artisanal producers as a strategy to produce a food ingredient with high nutritional value at low cost, reaching markets outside the production area.

Spray drying has been the most common technique used to produce powdered cheese (e.g., cheddar and parmesan powders); however, drying can affect flavor, color, texture, and reconstitution properties of the cheese powder [8–10]. Food matrices vary widely, so specific drying conditions must be determined to minimize their impact on structural properties [11,12]. To mitigate these effects, various biopolymers, such as maltodextrins and gums, have been used [13]. However, since spray drying is often inaccessible to small cheesemaking facilities, other drying options need to be evaluated.

Air-convective drying is one of the most common and simple methods for food dehydration, and due to its low cost, this technology can be an accessible option for this sector [14]. Producing requesón in powder form could be a viable option to extend its shelf life and expand its applications in the food ingredients sector. To the best of our knowledge, no previous studies have reported on the production of requesón powder. Therefore, the goal was firstly to select the optimal temperature of thermal dehydration, and secondly to analyze the impact of mesquite gum or guar gum on the drying process and the techno-functional properties of dried products.

2. Materials and Methods

2.1. Samples

Fresh samples from cow's cheese whey and requesón used in this study were obtained from a local artisanal cheesemaking producer of fresh cheese using whole (3.2% fat) unpasteurized cow's milk in Hermosillo, Sonora, Mexico.

Mesquite gum (*Neltuma velutina*), with an intrinsic viscosity $[\eta]$ of 6.9 mL/g and a molecular weight (Mw) of 625.9 kDa was donated by Laboratorio de Biopolímeros of CIAD. Guar gum (*Cyamopsis tetragonoloba*), with an intrinsic viscosity of 1331 mL/g and a molecular weight of 1400 kDa, was supplied by Sigma-Aldrich, Co., St. Louis, MO, USA.

2.2. Experimental Design

The study was conducted in two phases. The first phase aimed to determine the drying temperature that most effectively preserves the properties of requesón following reconstitution. The second phase sought to evaluate the type and concentration of gum that best preserves the characteristics of requesón during thermal drying at the selected optimal temperature.

To assess the impact of air-convective drying temperature on the properties of requesón powder, fresh requesón was dried at 40, 50, 60, and 70 °C, and moisture loss was evaluated every hour for each treatment until the final moisture content in each sample was reduced to below 5%. Drying was carried out using an Elite Gourmet air-convective food dehydrator (Model EFD308, Maxi-Matic, City of Industry, CA, USA). The air flow was at 0.19 m/s. Six circular stainless steel mesh trays (10 cm ID, 1 mm mesh size) were used per batch, with a total sample mass of 460 g. Each drying condition was conducted in duplicate.

To evaluate the protective effect of natural biopolymers during the thermal drying process, requesón samples containing mesquite and guar gums at two concentrations (0.25 and 0.5 g/L, based on preliminary studies) were prepared in the laboratory using sweet whey obtained from a local artisanal cheese factory. Requesón was produced following the protocol described by Mazorra-Manzano et al. (2019) [5], which involves heating the whey and maintaining it at 95 °C for 10 min to induce protein aggregation. The gums were incorporated into the whey and fully dissolved prior to the heat treatment. The resulting protein aggregates, which rose to the surface during heating, were collected using a mesh strainer and transferred to cheesecloth to remove excess liquid. Samples with and without added gums were prepared in duplicate. The yield of each batch was expressed as the weight (g) of fresh requesón obtained from each 100 mL of the whey used (% *w/v*). One portion of the fresh requesón was refrigerated at 4 °C for further analysis within 24 h, while the remaining portion was dried at the previously selected temperature of 50 °C for 8 h.

The dried samples were homogenized using a Nutribullet® Pro blender (Model NBR-0601, 900 W; Nutribullet, Capital Brands, Los Angeles, CA, USA) equipped with milling blades. The resulting material was passed through a No. 60 mesh sieve to obtain uniform requesón powders. The powders were then packaged in polyethylene bags and stored under refrigeration at 4 °C until further analysis.

2.3. Chemical Composition and pH

Protein content was measured by the Kjeldahl method (AOAC 991.20), fat content by the Gerber method (AOAC 989.05), moisture content by oven drying (AOAC 925.10), and ash content by incineration at 550 °C (AOAC 942.05) [15]. The pH of fresh requesón was measured using a Hanna model 2210 potentiometer (Hanna Instruments, Ciudad de Mexico, Mexico).

2.4. Water Holding Capacity (WHC)

The water holding capacity (WHC) of both fresh requesón and rehydrated requesón powder (adjusted to 30% total solids using deionized water and held at 4 °C for 60 min) was determined according to the method described by Diamantino et al. (2014) [16], with slight modifications. Briefly, 15 g of the requesón sample were placed in a 50 mL Falcon tube for centrifugation at 4000× g for 30 min at 20 °C using a Sorvall ST 16 centrifuge

(Thermo Fisher Scientific Inc., Osterode, Germany). WHC (%) was calculated using the following formula:

$$\text{WHC (\%)} = [1 - (B/A)] \times 100 \quad (1)$$

where A is the weight of the initial sample (g), and B is the weight of the liquid phase separated after centrifugation (g).

2.5. Texture

Texture profile analysis (TPA) of fresh and powdered-reconstituted requesón samples was conducted following the procedure outlined by Mazorra-Manzano et al. [5]. Hardness, cohesivity, and adhesivity were measured using a TMS-PRO texture analyzer (Food Technology Corporation, Sterling, VA, USA). Fresh and rehydrated samples (30% total solids) were used to fill the six wells (DI 34.8 mm, 9.5 cm², vol 16.8 mL) of a plastic cellular culture plate (Falcon, Corning Incorporated, New York, NY, USA). The samples were subjected to double penetration at 7.5 mm using a cylindrical probe (12.7 mm D, 18 mm H) at a speed of 1 mm/s and a pause time of 10 sec between penetrations. The test was performed on the six filled wells (n = 6), and the textural parameters of hardness, cohesivity, and adhesivity were determined from the graphs obtained using the Texture Lab Pro software (Food Technology Corporation, Sterling, VA, USA).

2.6. Color

The color of the requesón samples was determined by tristimulus colorimetry L, a, b, with a portable Minolta colorimeter (Chromameter CR400 Konica Minolta®, Tokyo, Japan). Five readings were taken at different sites on fresh, powdered, and rehydrated samples. Whiteness index was determined in duplicate using the following equation:

$$\text{Whiteness index (WI)} = 100 [(100 - L)^2 + a^2 + b^2]^{1/2} \quad (2)$$

2.7. Swelling Capacity (SC)

The swelling capacity of the requesón powder was determined following the methodology of Raghavendra et al. [17], which consisted of weighing 2 g of sample powder in a 10 mL graduated cylinder; then 10 mL of DI water was added and kept in refrigeration at 4 °C. After leaving the sample for 24 h for hydration, the volume occupied by the particles in the cylinder was registered. The SC was calculated using the following equation:

$$\text{SC (mL/g)} = V/P \quad (3)$$

where V is the volume of the hydrated sample (mL), and P is the weight of the initial sample (g).

2.8. Emulsifying Capacity (EC)

The emulsifying capacity of fresh and rehydrated requesón samples was determined following the procedure described by Pacheco-Aguilar et al. [18]. Briefly, 0.1 g of sample was homogenized in 100 mL of deionized water for 1 min using a blender (Oster Mexicana S.A., Tlalnepantla, EdoMex, México). Vegetable oil was then slowly added from a separatory funnel during continuous blending at maximum speed until the phase shifted from oil-in-water to water-in-oil. The volume of oil added was measured by weight, and the emulsifying capacity (EC) was expressed as milliliters of emulsified oil per 100 mL of 0.1% sample solution.

2.9. X-Ray Diffraction (XRD)

Requesón powder samples were analyzed by XRD using a Bruker X-ray diffractometer, D8 Advance Eco, with a copper source ($\text{CuK}\alpha = 1.5406 \text{ \AA}$) and a nickel filter. Diffractograms were obtained at 40 kV, 25 mA, range (2θ): 5–70, step time 0.3 s, step size 0.02° .

2.10. Scanning Electron Microscopy (SEM)

Images of powdered requesón samples were obtained using a scanning electron microscope SEM JEOL model 5410LV with an accelerating voltage of 20 kV and a working distance of 20 mm. For SEM observation, each sample was spread on double-sided copper tape and coated with gold using a JEOL 1200 ion sputter.

2.11. Statistical Analysis

A one-way analysis of variance (ANOVA) was conducted to evaluate the effect of drying temperature on the whiteness index (WI), water holding capacity (WHC), swelling capacity (SC), and texture (hardness, viscosity, and adhesivity). To evaluate the effect of biopolymer addition on the functional properties of whey cheese (requesón) dried at 50°C , a 2×2 factorial experimental design was used. Variable responses were color WI, WHC, SC, EC, and texture parameters. Subsequently, the Tukey–Kramer multiple comparison test was applied to assess differences between means at a significance level of 0.05. All statistical analyses were performed using NCSS 2023 software (NCSS, LLC, Kaysville, UT, USA).

3. Results and Discussion

3.1. Thermal Drying and Reconstitution Properties of Requesón

The fresh requesón used in this study to evaluate the effect of drying temperature had a pH range of 6.2 to 6.6, a moisture content of 77.4% (22.6% total solids), 9.5% protein, 2.2% fat, 2.7% ash, and 8.2% carbohydrates (by difference), values that fall within the normal range for this type of cheese. The moisture and protein contents are comparable to those reported by Mazorra-Manzano et al. [5], who found values of 76.7% and 9.4%, respectively. However, their study reported higher fat content (6.7%) and lower ash content (0.5%). Despite these variations, the protein and moisture levels in our sample remained within the typical range, as water contents between 70–80% are commonly observed in requesón [19]. Similarly, Wu et al. [20], using a mixture of cow's milk and goat's milk whey (80:20), reported water and fat contents of 78.8% and 2.3%, respectively, with slightly higher protein (11.8%) and lower ash content (0.6%). The chemical composition of requesón largely depends on the type and composition of the whey, as well as other ingredients such as milk solids or salt, which are commonly added to increase yield and impart a mildly salty flavor [13].

The water loss behavior during air-convective drying of requesón samples at 40, 50, 60, and 70°C is presented in Figure 1. A sample was considered fully dehydrated when water loss exceeded 90% or additional weight loss was less than 2% after 30 min in the dryer. Based on these criteria, complete dehydration was achieved after 6 h at 70°C , 8 h at 50°C and 60°C , and 12 h at 40°C . All the samples had a final moisture content of less than 5%, which is typical for dehydrated products. The visual appearance of all the dried requesón samples was similar regardless of the drying temperature (Figure 1).

During thermal dehydration, free water is removed from protein aggregates within the requesón matrix at different rates. This water loss likely promotes additional protein aggregation through enhanced hydrophobic interactions, resulting in a more rigid and agglomerate structure [21]. Although fat may also contribute to the structural characteristics of dried requesón, its effect is likely minimal due to the low fat content (2.7%). For comparison, Garcia-Valladares et al. [14] reported that cincho cheese (2.7% fat; commonly

consumed grated) dried in pieces of 0.5 mm at 50 °C, retained the organoleptic properties of fresh cheese.

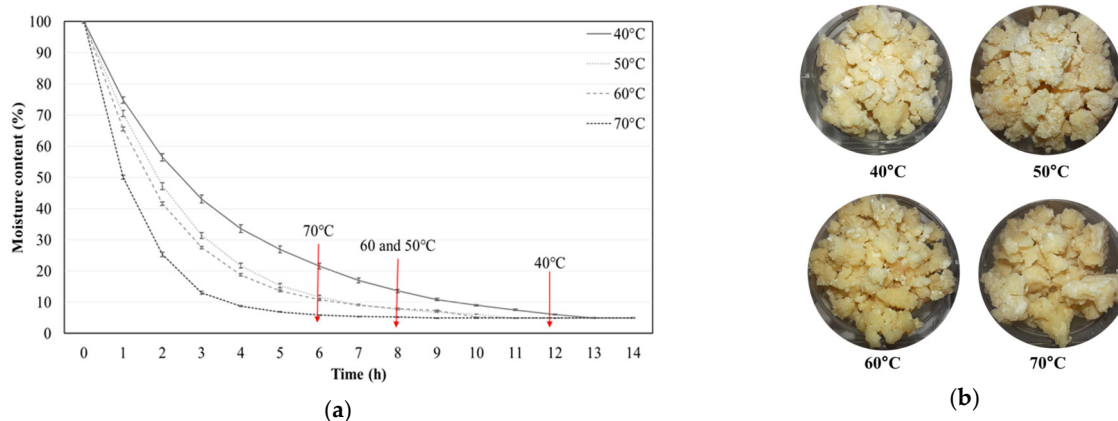


Figure 1. Drying of requesón at different temperatures: (a) moisture loss (%) during dehydration, and (b) visual appearance of requesón dehydrated at 40 °C for 12 h, 50 °C and 60 °C for 8 h, and 70 °C for 6 h.

The heat-dried requesón samples obtained at different temperatures (Figure 1) exhibited a hard, cracked texture and lacked hydration properties in their intact form. To enhance rehydration performance for further evaluation, the samples were milled to produce requesón powder. Color is a key physical attribute influencing consumer acceptance of cheese products [22]. Fresh requesón typically has a white appearance with a slightly yellowish-gray hue, which may be altered during thermal dehydration due to Maillard or caramelization reactions triggered by its high protein and lactose content [23].

The whiteness index (WI) for fresh requesón, powders of thermally dried requesón, and their rehydrated forms are shown in Table 1. For reference, a requesón powder was prepared using freeze-drying (lyophilization). The WI of the reconstituted freeze-dried requesón was nearly identical to that of fresh requesón (84.4 vs. 84.5), showing only a slight reduction before hydration (82.5), yet remained within acceptable values. In contrast, requesón powders obtained through thermal drying exhibited significantly lower WI values ($p < 0.05$), with the least color change observed in the sample dried at 50 °C (Table 1). Upon rehydration, the WI of powders dried at 60 and 70 °C increased significantly, whereas those dried at 40 and 50 °C exhibited no statistically significant change ($p > 0.05$). Belsito et al. [22] reported WI values ranging from 71 to 74 for requeijão cremoso, which are comparable to those observed for requesón powders in the present study (range 68–76).

Table 1. Effect of drying temperature on the whiteness index of the requesón powder before and after rehydration.

Powder		Rehydrated	
Treatment	Whiteness Index	Treatment	Whiteness Index
-	-	Fresh	84.4 ± 1.03 ^a
Freeze-dry	82.5 ± 0.82 ^a	Freeze-dry	84.5 ± 0.39 ^a
40 °C	73.6 ± 2.28 ^b	40 °C	74.9 ± 0.78 ^c
50 °C	76.1 ± 1.17 ^b	50 °C	76.8 ± 0.74 ^b
60 °C	68.8 ± 2.37 ^c	60 °C	78.2 ± 0.31 ^b
70 °C	67.8 ± 2.45 ^c	70 °C	77.0 ± 0.72 ^b

Means within the same column followed by different lowercase letters differ significantly ($p < 0.05$).

The hydration properties of the requesón powders, assessed through their swelling capacity (SC), are presented in Table 2. The results indicate that thermal dehydration

had a significant impact on the swelling capacity (SC) of requesón powder. All thermally dehydrated samples exhibited lower SC values compared to the lyophilized requesón powder used as a reference, which had an SC of 4.53 mL/g. Among the thermally treated samples, dehydration at 50 °C resulted in the least reduction in SC (3.20 mL/g), while the remaining treatments produced values ranging from 2.9 to 3.0 mL/g (Table 2). Additionally, thermal dehydration negatively impacted the water holding capacity (WHC), leading to an approximate 25% reduction across all treatments (Figure 2). Based on the data, it is evident that all evaluated thermal drying conditions adversely affected the hydration-related functional properties of the requesón powders. However, dehydration at 50 °C for 8 h caused the least detrimental effect and was therefore selected for subsequent evaluation of the protective effects of gums on the functional properties of requesón powder produced by thermal dehydration.

Table 2. Effect of drying temperature on the swelling capacity of requesón powder.

Treatment	Swelling Capacity (mL/g)
Freeze-dry (reference)	4.53 ± 0.07 ^a
40 °C	2.93 ± 0.07 ^c
50 °C	3.20 ± 0.03 ^b
60 °C	3.03 ± 0.03 ^c
70 °C	2.97 ± 0.05 ^c

Means with different lowercase letters within a column differ significantly ($p < 0.05$).

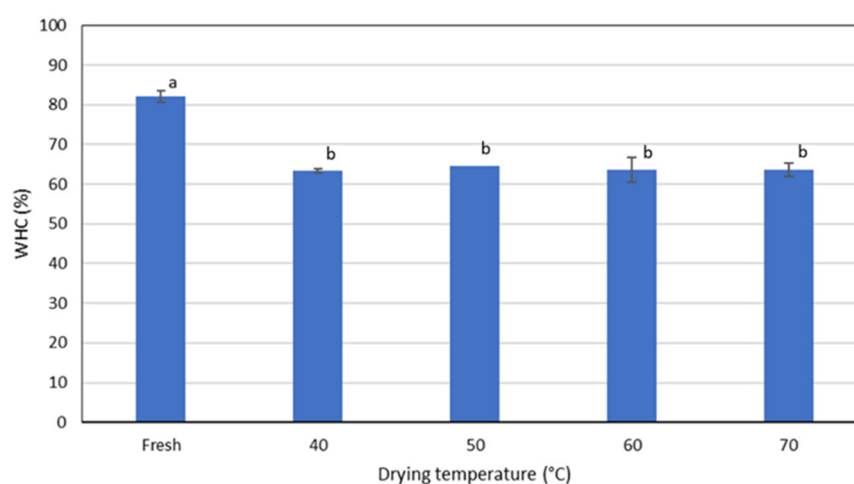


Figure 2. Effect of drying temperature on the water holding capacity (WHC) of rehydrated requesón powder. Bars represent the means ± SD from two independently dried, powdered, and rehydrated samples, each analyzed in triplicate. Bars with different letters indicate significant differences ($p < 0.05$).

Notably, the WHC, hardness, and cohesivity of the lyophilized requesón powder after rehydration were comparable to those of fresh requesón (Table 3). These findings are consistent with previous studies reporting analogous textural characteristics in fresh requesón [5,24]. Figure 3A,B illustrates the visual appearance of fresh requesón and its powdered counterparts (both thermally dehydrated and lyophilized) before and after rehydration. A notable similarity was observed between fresh requesón and rehydrated lyophilized samples. In contrast, thermally dehydrated powders (50 °C, 8 h) displayed a more compact texture and the presence of partially rehydrated particles after 24 h at 4 °C, highlighting their inferior hydration performance as previously discussed.

Table 3. Textural properties and water holding capacity of fresh requesón and rehydrated requesón powder obtained by lyophilization.

Requesón	WHC (%)	Hardness (N)	Cohesiveness	Adhesiveness (-N)
Fresh (control)	82.1 ± 3.0	0.89 ± 0.3	0.54 ± 0.05	0.81 ± 0.14
Rehydrated Freeze-dried	79.2 ± 1.5	0.69 ± 0.1	0.52 ± 0.02	0.39 ± 0.10

Values represent the means ± SD from two samples.

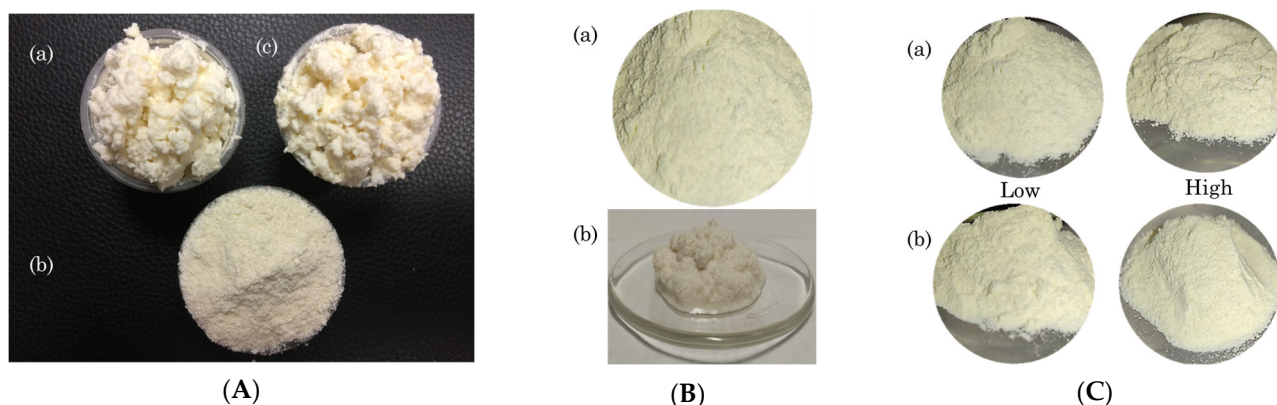


Figure 3. Visual appearance of fresh, powdered, and rehydrated requesón. (A) (a) Fresh requesón, (b) lyophilized requesón powder, and (c) lyophilized requesón after rehydration. (B) (a) Requesón powders obtained by thermal dehydration and (b) thermally dried requesón powders after rehydration. (C) Thermally dried requesón powders formulated with biopolymers: (a) mesquite gum (MG) and (b) guar gum (GG), each added at low (0.25 g/L) and high (0.5 g/L) concentrations.

3.2. Protective Effect of Biopolymers on the Functional Properties of Requesón Powder Produced by Thermal Dehydration

The incorporation of biopolymers during requesón production was investigated in this study due to their widespread use and established functional roles in the formulation of commercial cheese powders. The resulting requesón powders with added biopolymers are shown in Figure 3C. No discernible differences in visual appearance were observed between samples containing mesquite gum (MG) and guar gum (GG), regardless of the concentration used. As presented in Table 4, within the same sample type (fresh, powdered, and rehydrated requesón), the inclusion of gums did not significantly ($p > 0.05$) alter their WI, with all the samples exhibiting WI values above 80. These values are considered desirable for whey-derived cheeses and their powdered forms [19]. Furthermore, the addition of biopolymers led to an increase in requesón yield (Table 5). However, this increase was attributed primarily to the higher water content in the requesón imparted by the gums, as the total solids recovery remained consistent across all treatments. Consequently, this apparent yield enhancement was associated with a relative dilution effect, as evidenced by the reduced concentrations of protein and fat in the requesón produced. Similar trends regarding improved yield and moisture retention upon gum addition in whey cheeses, such as ricotta, have been previously reported [25].

The incorporation of the biopolymers MG and GG at both tested concentrations did not significantly enhance ($p > 0.05$) the WHC in fresh requesón (Figure 4), despite these samples exhibiting slightly higher moisture content compared to the control (without biopolymers) (Table 5). These results suggest that water had limited interaction with the incorporated polymers. Given the high protein content of requesón, it is anticipated that thermal drying would compromise its functional properties. Indeed, the WHC of all rehydrated requesón powders containing biopolymers was comparable to that of the control sample ($p > 0.05$),

indicating that the addition of MG and GG did not prevent or improve the loss of WHC caused by thermal dehydration.

Table 4. Whiteness index of fresh, powdered, and rehydrated requesón with mesquite gum (MG) and guar gum (GG) at low and high concentrations.

Whiteness Index			
Requesón	Fresh	Powdered	Rehydrated
Control	86.7 ± 0.1	81.6 ± 0.9	80.9 ± 0.7
MG [0.25 g/L]	86.5 ± 0.1	81.7 ± 0.5	80.7 ± 0.1
MG [0.5 g/L]	85.2 ± 0.1	82.5 ± 1.4	80.9 ± 0.1
GG [0.25 g/L]	85.7 ± 0.1	83.3 ± 2.5	82.1 ± 0.7
GG [0.5 g/L]	85.5 ± 0.6	82.5 ± 1.3	82.1 ± 0.1

Values represent the means of two requesón samples with mesquite gum (MG) and guar gum (GG) added at low (0.25 g/L) and high (0.50 g/L) concentrations. Control = requesón without added biopolymers. Values within the same column are not significantly different ($p > 0.05$).

Table 5. Yield and chemical composition of fresh requesón with added gums (MG and GG).

Requesón	Yield	Moisture	Protein	Fat	Ash	Total Solids Recovery *
Control	5.4	76.2	9.4	4.0	0.4	13.2
MG [0.25 g/L]	5.4	75.8	9.4	5.3	0.4	13.4
MG [0.5 g/L]	6.0	77.4	8.2	5.6	0.4	13.9
GG [0.25 g/L]	6.3	79.0	7.6	3.6	0.5	13.0
GG [0.5 g/L]	6.2	80.0	7.1	3.5	0.6	13.6

Values (%) represent the means of two fresh requesón samples produced with mesquite gum (MG) and guar gum (GG) at low (0.25 g/L) and high (0.50 g/L) concentrations. Control = requesón without added biopolymers. * g/L.

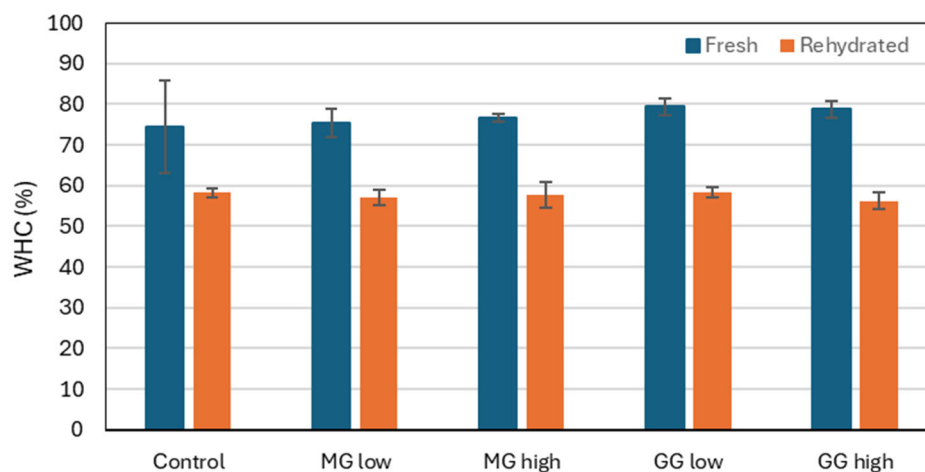


Figure 4. Effect of biopolymer addition on the water holding capacity (WHC) of fresh and thermally dried requesón after hydration. Bars represent means of two requesón samples with mesquite gum (MG) and guar gum (GG) added at low (0.25 g/L) and high (0.50 g/L) concentrations. Control = requesón without biopolymers. Values within the same group (fresh or rehydrated) are not significantly different ($p > 0.05$).

In contrast, biopolymer inclusion significantly increased ($p < 0.05$) the swelling capacity (SC) of the requesón powders compared to the control ($p < 0.05$) (Table 6). Furthermore, the emulsifying capacity (EC) of the requesón powders was enhanced by a high concentration of MG and both concentrations of GG, yielding values comparable ($p > 0.05$) to the fresh requesón without biopolymers. This improvement may be attributed to the intrinsic emulsifying properties of the added gums and their interactions with protein aggregates during drying and rehydration [7,26].

Table 6. Effect of biopolymer type and concentration added during requesón production on emulsifying capacity (EC) and swelling capacity (SC).

Requesón	Swelling Capacity (mL/g)	Emulsifying Capacity (g oil/100 mL 0.1% Requesón Solution)
Fresh (w/o biopolymer)	--	71.7 ± 1.0 ^{ab}
Powder (w/o biopolymer)	2.84 ± 0.06 ^c	60.8 ± 2.5 ^d
Powder MG [0.25 g/L]	3.11 ± 0.07 ^{bc}	66.3 ± 1.6 ^c
Powder MG [0.5 g/L]	3.44 ± 0.37 ^b	67.8 ± 1.2 ^b
Powder GG [0.25 g/L]	3.11 ± 0.14 ^{bc}	71.0 ± 1.4 ^b
Powder GG [0.5 g/L]	3.81 ± 0.24 ^a	73.5 ± 1.0 ^{ab}

Values represent the means of two requesón samples analyzed in triplicate. Mesquite gum (MG) and guar gum (GG) were added at low (0.25 g/L) and high (0.50 g/L) concentrations during production. For EC analysis, samples were adjusted to a final solid content of 0.1%. Values with different superscripts differ significantly ($p < 0.05$).

Polysaccharides (hydrocolloids) are incorporated into dairy products such as yogurt and ice cream to enhance texture and improve stability; however, they are not common in either cheese or whey cheese. Nevertheless, Hesarinejad et al. [25] evaluated the addition of gelatin/guar gum mixture to improve the rheological and textural properties of restructured fresh ricotta cheese but did not achieve the formation of a strong ricotta gel. On the contrary, Belsito et al. [22] adding oligosaccharides to requesón cremoso improved its softness and spreadability and positively impacted the aroma and taste. The present study investigates the effects of incorporating hydrophilic biopolymers, mesquite gum (MG) and guar gum (GG), at low (0.25 g/L) and high (0.5 g/L) concentrations during requesón production. Table 7 summarizes their impact on the textural properties of both fresh and rehydrated requesón powders. Adding biopolymers to fresh requesón resulted in variable effects on textural properties. Although a slight, non-significant increase in hardness ($p > 0.05$) was observed with 0.25 g/L of MG, the remaining treatments, particularly those involving GG tended to reduce hardness, with the most pronounced decrease observed at 0.5 g/L GG ($p < 0.05$). In contrast, gum addition did not significantly affect cohesiveness or adhesiveness, as no differences were observed across treatments for these parameters ($p > 0.05$). A similar trend was observed in the hardness of the rehydrated requesón powders. Only the formulation containing 0.25 g/L of MG showed a slight, non-significant increase in hardness ($p > 0.05$), while the remaining treatments, especially those with GG, led to a reduction in this parameter. In contrast, the incorporation of biopolymers positively influenced both cohesiveness and adhesiveness, particularly cohesiveness at high concentration (0.5 g/L) (Table 7), which indicates enhanced interactions during reconstitution.

Table 7. Effect of mesquite gum (MG) and guar gum (GG) addition at low (0.25 g/L) and high (0.5 g/L) concentrations during requesón production on textural parameters of fresh and rehydrated powdered requesón.

Requesón	Hardness (N)		Cohesiveness		Adhesiveness (-N)	
	Fresh	Rehydrated	Fresh	Rehydrated	Fresh	Rehydrated
Control	1.72 ± 0.2 ^a	2.41 ± 0.2 ^{ab}	0.54 ± 0.1 ^a	0.30 ± 0.1 ^b	1.83 ± 0.7 ^a	1.59 ± 0.8 ^a
MG low level	1.97 ± 0.1 ^a	2.76 ± 0.3 ^{ab}	0.54 ± 0.1 ^a	0.33 ± 0.1 ^b	2.43 ± 0.3 ^a	1.66 ± 0.9 ^a
MG high level	1.64 ± 0.2 ^a	2.17 ± 0.3 ^b	0.47 ± 0.1 ^a	0.37 ± 0.1 ^{ab}	1.58 ± 0.7 ^a	1.20 ± 0.2 ^a
GG low level	1.58 ± 0.1 ^a	1.48 ± 0.4 ^c	0.55 ± 0.1 ^a	0.41 ± 0.1 ^{ab}	1.64 ± 0.3 ^a	1.74 ± 0.6 ^a
GG high level	0.85 ± 0.3 ^b	1.74 ± 0.3 ^{bc}	0.58 ± 0.1 ^a	0.49 ± 0.1 ^a	0.70 ± 0.2 ^a	2.40 ± 0.3 ^a

Values represent the means of two requesón samples with mesquite gum (MG) and guar gum (GG) added at low (0.25 g/L) and high (0.50 g/L) concentrations. Control = requesón made without biopolymer addition. The mean values in the same column with different lowercase letters differ significantly ($p < 0.05$).

3.3. Structural Properties of Requesón Powders

The observed loss of hydration properties in requesón powders subjected to thermal dehydration may be attributed to the mechanisms of water removal and the resulting changes in the microstructure of the dried product, particularly in terms of porosity and pore size distribution. Freeze-drying is widely recognized as a gentle dehydration technique that preserves the structural integrity of food matrices, owing to the sublimation of ice under low-pressure and temperature conditions. This process minimizes structural collapse, compaction, and component aggregation [27]. In contrast, thermal dehydration, characterized by water removal through vaporization, can intensify molecular interactions among food components and promote further aggregation of proteins and agglomerate particles formed during requesón production. These interactions are likely to reduce the overall porosity and increase the structural compactness of the resulting powder particles, thereby diminishing their capacity for water uptake upon rehydration [21].

The structural effects of the drying method on requesón powder are shown in the micrographs presented in Figure 5. The requesón powder obtained by freeze-drying exhibited a porous surface with small cavities, indicating minimal structural collapse. In contrast, the thermally dehydrated powder showed surface compaction and the formation of small aggregates, with markedly reduced porosity, an essential feature for effective hydration, consistent with previous observations [7]. Additionally, particle size, shape, and distribution influence rehydration properties [28].

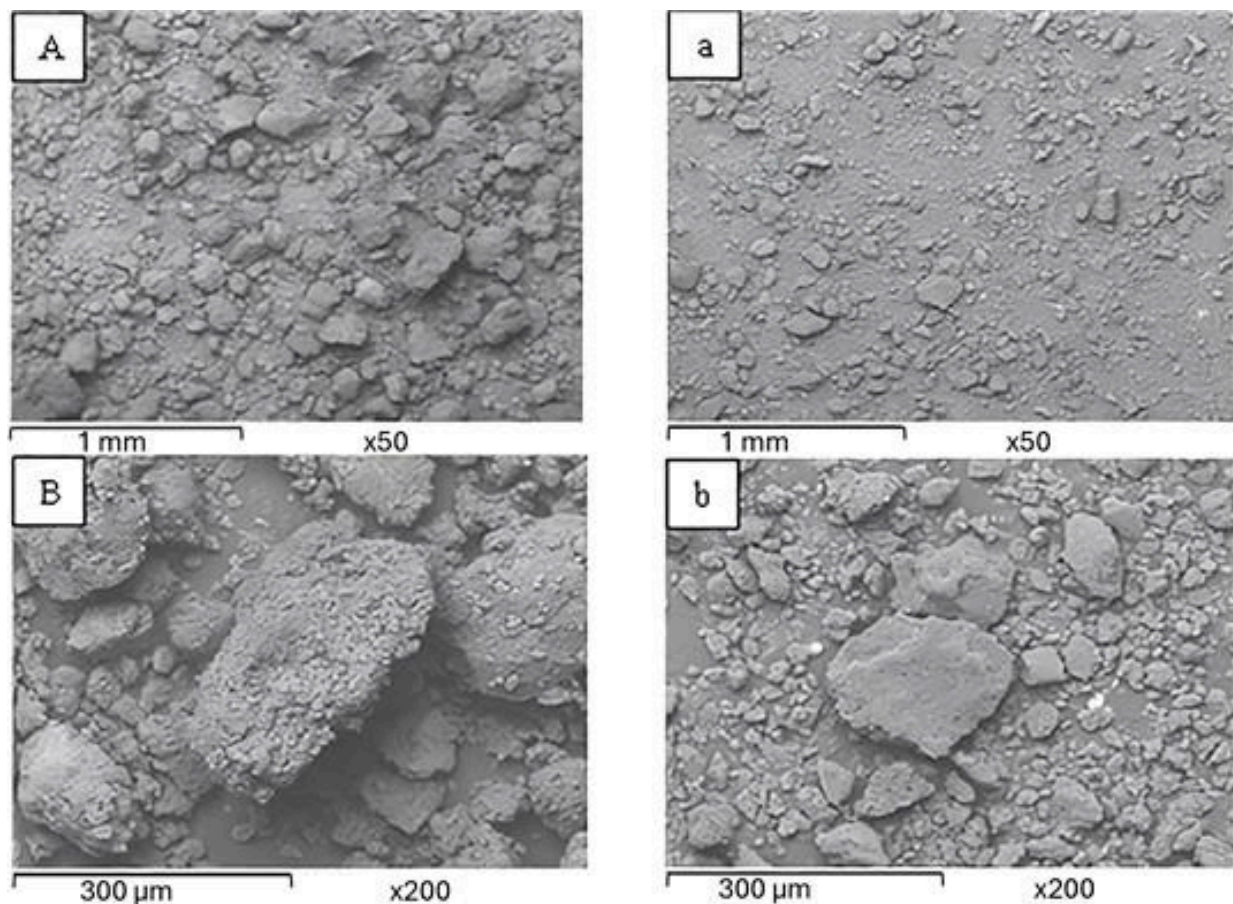


Figure 5. Cont.

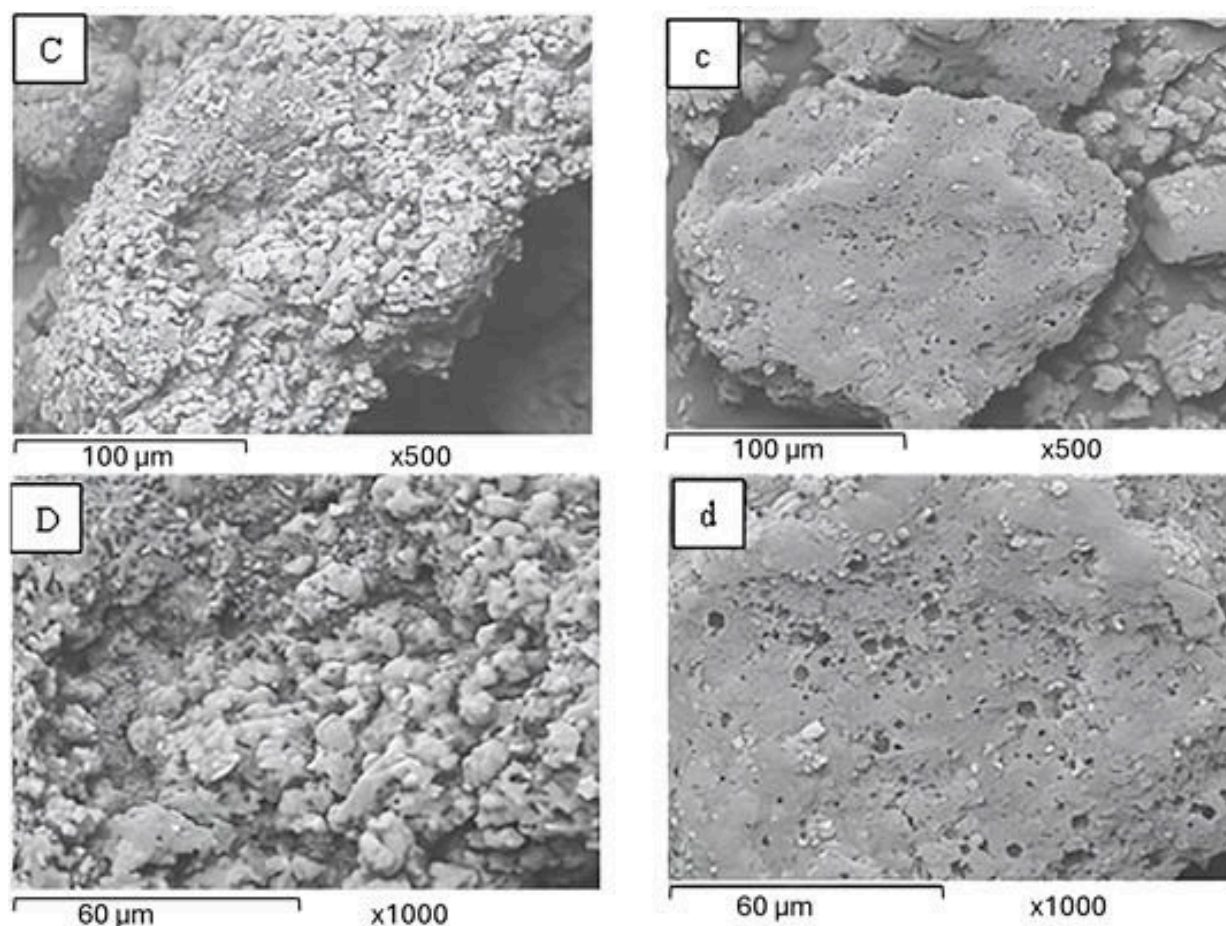


Figure 5. Micrographs of requesón powder obtained by heat drying (A–D) and lyophilization (a–d) at different magnifications. Samples were sifted through a #60 mesh. Scale bars: 1 mm (A,a), 300 µm (B,b), 100 µm (C,c), and 600 µm (D,d).

Most commercial cheese powders incorporate biopolymers and are typically produced via spray drying. However, thermal drying has rarely been applied to cheese products and is often considered unsuitable for certain types of cheese. For instance, drying mozzarella cheese above 30 °C has been reported to result in oil separation and structural degradation (Hwang et al., 2015) [29]. Given that requesón is produced through heat-induced protein aggregation and lacks a well-defined structure, we hypothesized that incorporating biopolymers (gums) could help mitigate the detrimental effects of thermal dehydration. Specifically, it is proposed that biopolymers may interact with protein aggregates to form “stabilizing bridges”, thereby reducing protein-protein aggregation during drying and enhancing the reconstitution properties of the resulting powder [19,22].

Structural analysis via X-ray diffraction (XRD) (Figure 6) supports this hypothesis only partially. The requesón powder obtained through freeze-drying displayed an amorphous structure, as evidenced by a smooth diffractogram with low-intensity, broad peaks, indicating minimal crystallinity and structural damage (Figure 6a). In contrast, powders subjected to thermal dehydration exhibited intense, sharp peaks in the diffractograms, indicative of increased crystallization and molecular aggregation. Moreover, the addition of biopolymers (MG and GG) did not prevent or significantly reduce aggregate formation during heat drying, as the crystalline structures were still evident in the corresponding XRD patterns (Figure 6b).

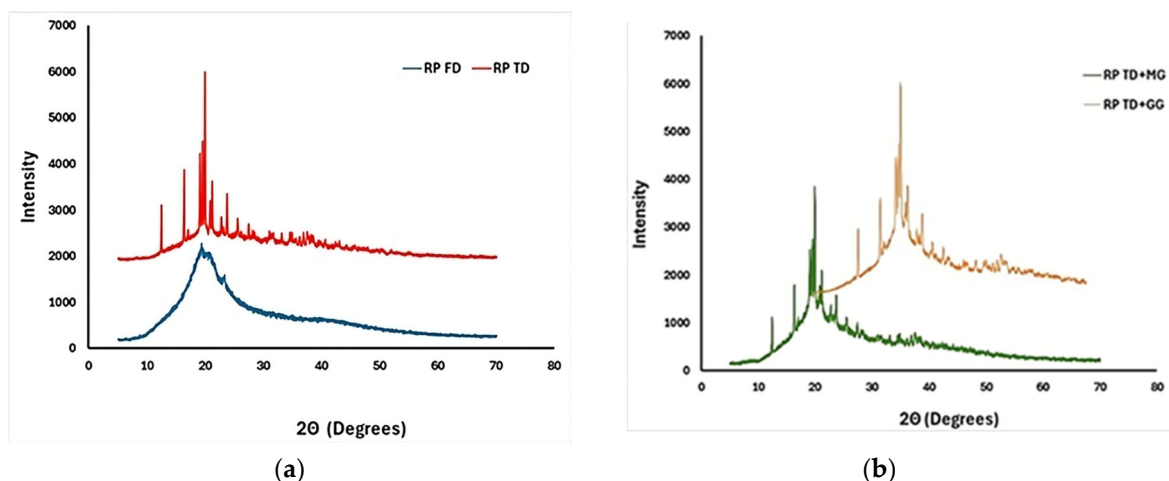


Figure 6. X-Ray diffraction of requesón powders: (a) XRD pattern for requesón powder obtained by thermal drying (RP TD) and by lyophilization (RP FD), and (b) requesón powder obtained by thermal drying added with mesquite gum (RP TD +MG) and guar gum (RP TD +GG) during its production.

4. Conclusions

Thermal dehydration negatively affected the rehydration properties of the requesón powder when compared to freeze-drying, which better preserved the characteristics of fresh requesón. Of all the functional parameters evaluated, the whiteness index was the least impacted by the drying method. The addition of mesquite gum and guar gum during production provided a partial protective effect, particularly improving emulsifying capacity, swelling capacity, and some textural attributes, depending on the concentration used. However, these enhancements were limited; no significant improvement in water holding capacity was observed, and the gains in swelling capacity were small. Overall, while the use of hydrophilic biopolymers offers some functional benefits, it does not fully counteract the adverse effects of thermal dehydration on requesón powder.

Despite certain limitations, the requesón powders, both with and without added biopolymers, demonstrated hydration properties that support their potential use as protein-rich, functional ingredients in food formulations. This approach presents a feasible strategy for small-scale and artisanal cheese producers to valorize whey, contributing to waste reduction and product diversification.

Further studies using other types of polysaccharides, mixtures, and higher concentrations are recommended. The microbiological stability, as well as the functional and sensory property changes of requesón powder over storage time and its application in food products, require further investigation.

Author Contributions: Project administration, Funding acquisition, and Supervision M.A.M.-M.; Conceptualization, M.A.M.-M. and A.M.-G.; methodology and formal analysis, A.M.-G., J.G.T.-P., M.E.L.-S. and F.B.-B.; validation and data curation, M.A.M.-M., A.M.-G., J.C.R.-S., M.J.T.-L. and Y.L.L.-F.; writing—original draft preparation, M.A.M.-M. and A.M.-G.; writing—review and editing, M.A.M.-M. and J.C.R.-S. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by the National Council of Humanities, Science and Technology (CONAHCYT; Mexico City, Mexico). Research Project Grant PDCPN2014-1 No. 248100.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

Acknowledgments: The authors express their gratitude to the National Council of Humanities, Science and Technology (CONAHCYT) of México for the Master’s scholarship awarded to coauthor Angelica Martinez Garcia.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of this study; in the collection, analysis, or interpretation of the data; in the writing of the manuscript; or in the decision to publish the results.

References

1. USDA. Available online: <https://www.fas.usda.gov/data/production/commodity/0240000> (accessed on 3 May 2025).
2. Chamundeshwari, J.; Parthasarathi, S.; Ali, R. Spray drying of milk and milk products. In *Spray Drying for the Food Industry: Unit Operations and Processing Equipment in the Food Industry*; Jafari, S.M., Samborska, K., Eds.; Woodhead Publishing: Cambridge, UK, 2023; Chapter 4, pp. 87–123.
3. Buchanan, D.; Martindale, W.; Romeih, E.; Hebishy, E. Recent advances in whey processing and valorisation: Technological and environmental perspectives. *Int. J. Dairy Technol.* **2023**, *76*, 292–312. [CrossRef]
4. Bintsis, T.; Papademas, P. Sustainable approaches in whey cheese production: A review. *Dairy* **2023**, *4*, 249–270. [CrossRef]
5. Mazorra-Manzano, M.A.; Ramírez-Montejo, H.; Lugo-Sánchez, M.E.; González-Córdova, A.F.; Vallejo Córdoba, B. Characterization of whey and whey cheese requesón from the production of asadero cheese (cooked cheese) Sonoran region. *Nova Sci.* **2019**, *23*, 220–233. [CrossRef]
6. Alemán-Mateo, H.; Carreón, V.R.; Macías, L.; Astiazaran-García, H.; Gallegos-Aguilar, A.C.; Enríquez, J.R. Nutrient-rich dairy proteins improve appendicular skeletal muscle mass and physical performance and attenuate the loss of muscle strength in older men and women subjects: A single-blind randomized clinical trial. *Clin. Interv. Aging.* **2014**, *12*, 1517–1525. [CrossRef] [PubMed]
7. Félix da Silva, D.; Larsen, F.; Hougaard, A.; Ipsen, R. The influence of raw material, added emulsifying salt and spray drying on cheese powder structure and hydration properties. *Int. Dairy J.* **2017**, *74*, 27–38. [CrossRef]
8. Félix da Silva, D.; Hirschberg, C.; Ahrné, L.; Hougaard, A.B.; Ipsen, R. Cheese feed to powder: Effects of cheese age, added dairy ingredients and spray drying temperature on properties of cheese powders. *J. Food Eng.* **2018**, *237*, 215–225. [CrossRef]
9. Domínguez-Niño, A.; Buendía-González, A.; Cantú-Lozano, D.; Andrade-González, I.; Luna-Solano, G. Efecto del secado por lecho fluidizado sobre las propiedades fisicoquímicas y microbiológicas de queso fresco mexicano. *Rev. Mex. Ing. Quím.* **2016**, *15*, 869–881.
10. Jaafar, F.E.; Rubaiy, H.H.; Niamah, A.K. Effect of Different Air Oven Temperatures on Chemical, Physical, and Microbial Properties of Dried Bio-Yoghurt Product. *Dairy* **2024**, *5*, 44–53. [CrossRef]
11. Michailidis, P.A.; Krokida, M.K. Drying and Dehydration Processes in Food Preservation and Processing. In *Conventional and Advanced Food Processing Technologies*; Bhattacharya, S., Ed.; John Wiley & Sons, Ltd.: Chichester, UK, 2014; pp. 1–21.
12. Pinho, A.; Assis, F.; Peres, A.; Pintado, M.; Morais, A.M.M.B. Dehydration of cheese by hot air, microwave and freeze-drying. *Chem. Chem. Eng. Biotechnol. Food Ind.* **2017**, *18*, 455–460.
13. Erbay, Z.; Koca, N. Effects of whey or maltodextrin addition during production on physical quality of white cheese powder during storage. *J. Dairy Sci.* **2015**, *98*, 8391–8404. [CrossRef]
14. Garcia-Balladares, O.; López-Vidaña, E.C.; Galindo-Luna, Y.R.; Luna-Solano, G.; Pilatowsky-Figueroa, I.; Domínguez-Niño, A. Effect of convective drying conditions on the physicochemical, microbiological, and thermophysical properties of cincho artisanal cheese. *Rev. Mex. Ing. Quím.* **2022**, *21*, 1–14. [CrossRef]
15. AOAC. *International, Official Methods of Analysis of the Association of Official Analytical Chemists*, 17th ed.; AOAC: Washington, DC, USA, 2000.
16. Diamantino, V.R.; Beraldo, F.A.; Sunakozawa, T.N.; Penna, A.L.B. Effect of octenyl succinylated waxy starch as a fat mimetic on texture, microstructure and physicochemical properties of Minas fresh cheese. *LWT—Food Sci. Technol.* **2014**, *56*, 356–362. [CrossRef]
17. Raghavendra, S.N.; Rastogi, N.K.; Raghavarao, K.S.M.S.; Tharanathan, R.N. Dietary fiber from coconut residue: Effects of different treatments and particle size on the hydration properties. *Eur. Food Res. Technol.* **2004**, *218*, 563–567. [CrossRef]
18. Pacheco-Aguilar, R.; Mazorra-Manzano, M.A.; Ramírez-Suárez, J.C. Functional properties of fish protein hydrolysates from Pacific whiting (*Merluccius productus*) muscle produced by a commercial protease. *Food Chem.* **2008**, *109*, 782–789. [CrossRef] [PubMed]
19. Silva Borba, K.K.; Silva, F.A.; Madruga, M.S.; Queiroga, C.R.E.R.; Souza, E.L.; Magnani, M. The effect of storage on nutritional, textural and sensory characteristics of creamy ricotta made from whey as well as cow’s milk and goat’s milk. *Int. J. Food Sci. Technol.* **2014**, *49*, 1279–1286. [CrossRef]
20. Wu, C.S.; Guo, J.H.; Lin, M.J. Stability evaluation of pH-adjusted goat milk for developing ricotta cheese with a mixture of cow cheese whey and goat milk. *Foods* **2020**, *9*, 366. [CrossRef] [PubMed]

21. Richards, N.; Barreto, I.; Borges, L.J. Muestras de quesos comerciales deshidratadas por proceso de microondas al vacío. *Tecnol. Láctea Latam.* **2016**, *95*, 58–61.
22. Belsito, P.C.; Ferreira, M.V.S.; Cappato, L.P.; Cavalcanti, R.N.; Vidal, V.A.S.; Pimentel, T.C.; Esmerino, E.A.; Balthazar, C.F.; Neto, R.P.C.; Tavares, M.I.B.; et al. Manufacture of Requeijao cremoso processed cheese with galactooligosaccharide. *Carbohydr Polym.* **2017**, *174*, 869–875. [[CrossRef](#)]
23. Hiroshi, S.; Guemra, H.; Bosso, S.; Pádua, A.E.; Ito, M.L.R. Protein and glucose reduction by Maillard reaction in milk with hydrolyzed lactose. *Rev. Chil. Nutr.* **2020**, *47*, 14–21.
24. Ramírez-Rivas, I.K.; Chávez-Martínez, A. Efecto del ultrasonido aplicado al suero de leche previo al calentamiento en la elaboración de requesón. *Interciencia* **2017**, *42*, 828–833.
25. Hesarinejad, M.A.; Lorenzo, J.M.; Rafe, A. Influence of gelatin/guar gum mixture on the rheological and textural properties of restructured ricotta cheese. *Carbohydr. Polym. Technol. Appl.* **2021**, *100162*, 2666–8939. [[CrossRef](#)]
26. Deshwal, G.K.; Akshit, F.N.U.; Altay, I.; Huppertz, T. A Review on the Production and Characteristics of Cheese Powders. *Foods* **2024**, *13*, 2204. [[CrossRef](#)] [[PubMed](#)]
27. Tastemirova, U.; Mukhtarkhanova, R.; Alimardanova, M.; Alibekov, R.; Shingisov, A. Impact of vacuum freeze-drying on the reconstituted camel milk composition. *Food Sci. Technol.* **2022**, *42*, e61722. [[CrossRef](#)]
28. Dodds, J. Techniques to analyse particle size of food powders. In *Handbook of Food Powders*; Bhandari, B., Bansal, N., Zhang, M., Schuck, P., Eds.; Woodhead Publishing: Cambridge, UK, 2013; pp. 309–338.
29. Hwang, I.S.; Lee, K.B.; Shin, Y.K.; Baik, M.Y.; Kim, B.Y. Effect of drying and storage on the rheological characteristics of mozzarella cheese. *Food Sci. Biotechnol.* **2015**, *24*, 2041–2044. [[CrossRef](#)]

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